

Factors Affecting Critical Currents in Coated Conductors

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*Superconductivity Technology Center
Los Alamos National Laboratory*

Factors Affecting Critical Currents in Coated Conductors

Microstructural properties

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Objective

To explore the fundamental correlation between the structural and the transport properties of coated conductors through comparative study of YBCO films on crystal and IBAD MgO substrates

Benefit

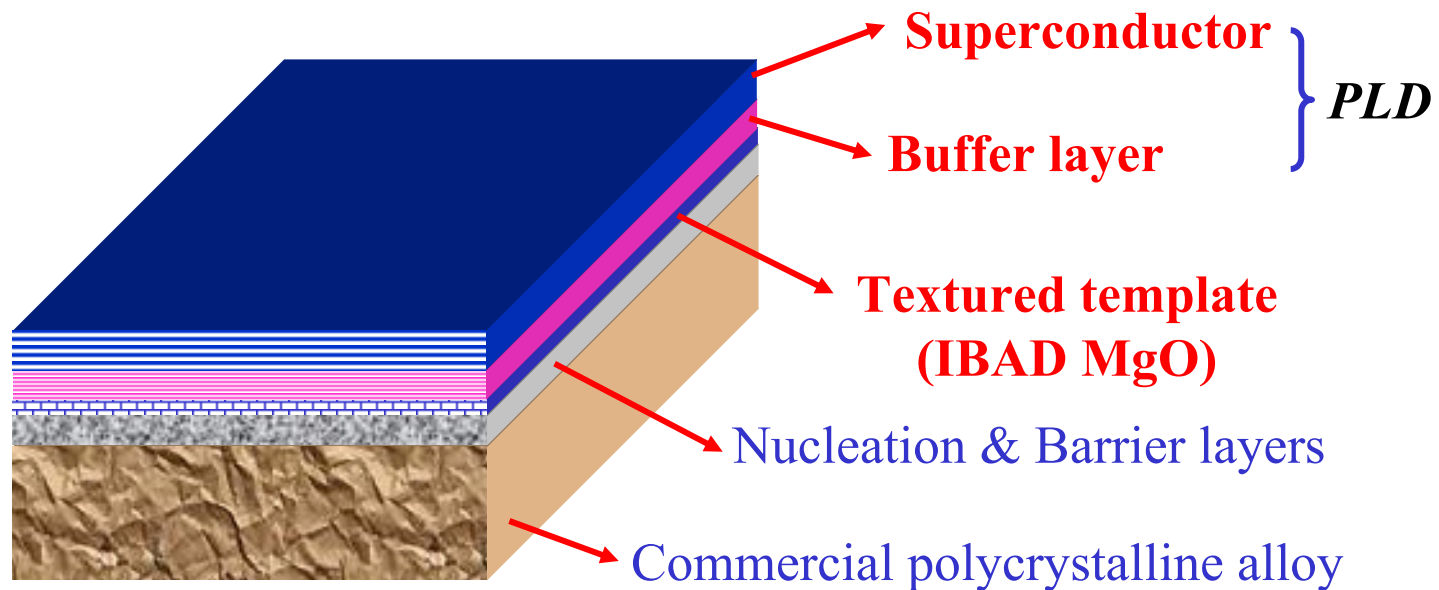
A more controllable and reproducible process to fabricate high performance coated conductors could be developed.

Outline

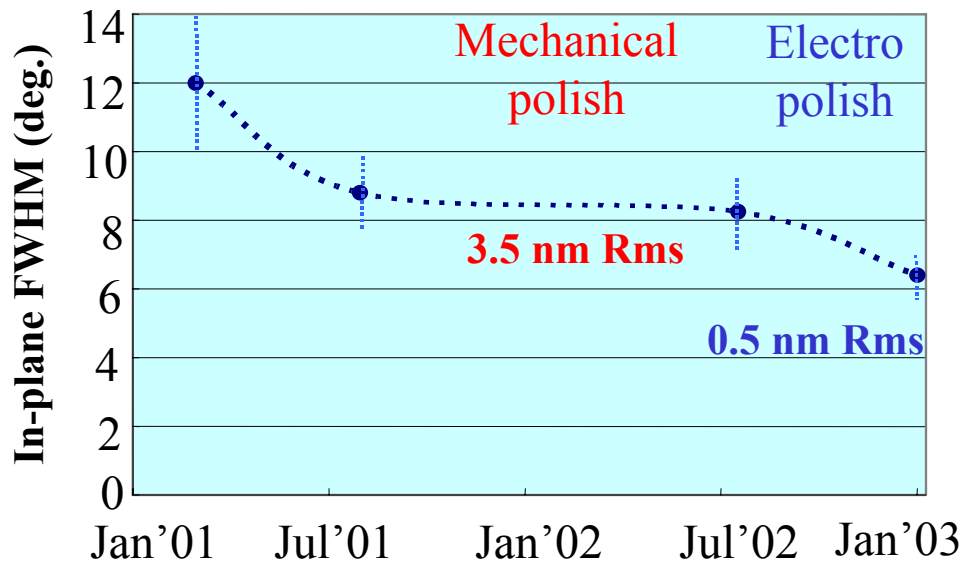
- Introduction
- Comparative study of the microstructures of YBCO films on crystal and IBAD MgO
- Comparison of J_c vs. thickness of as-deposited and ion-milled YBCO films on crystal and IBAD MgO
- Summary

LANL uses IBAD MgO on commercial polycrystalline alloys to develop coated conductors

- On a single crystal substrate, texture is derived from homo- and/or hetero-epitaxial growth at elevated temperature.
- On a polycrystalline substrate, a textured template must be provided before growth of desired epi-layers.

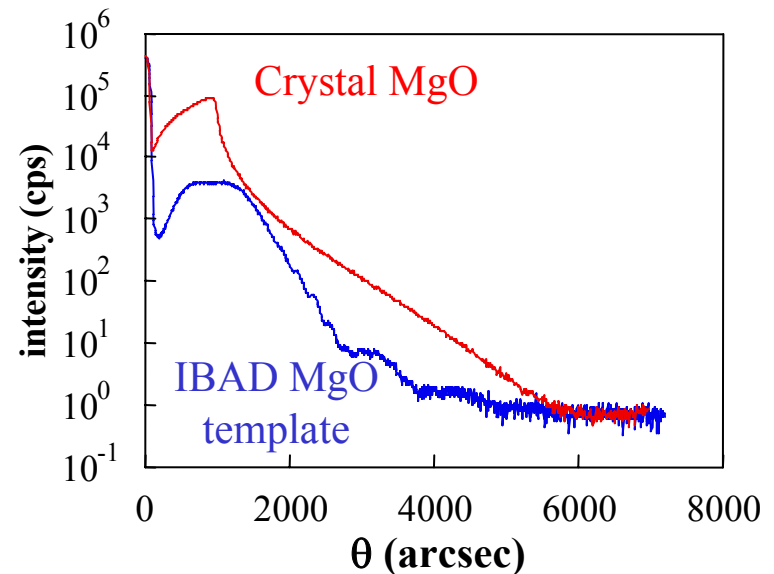


A smooth and highly crystalline IBAD MgO surface makes it possible for subsequent epitaxial growth of buffer and HTS films

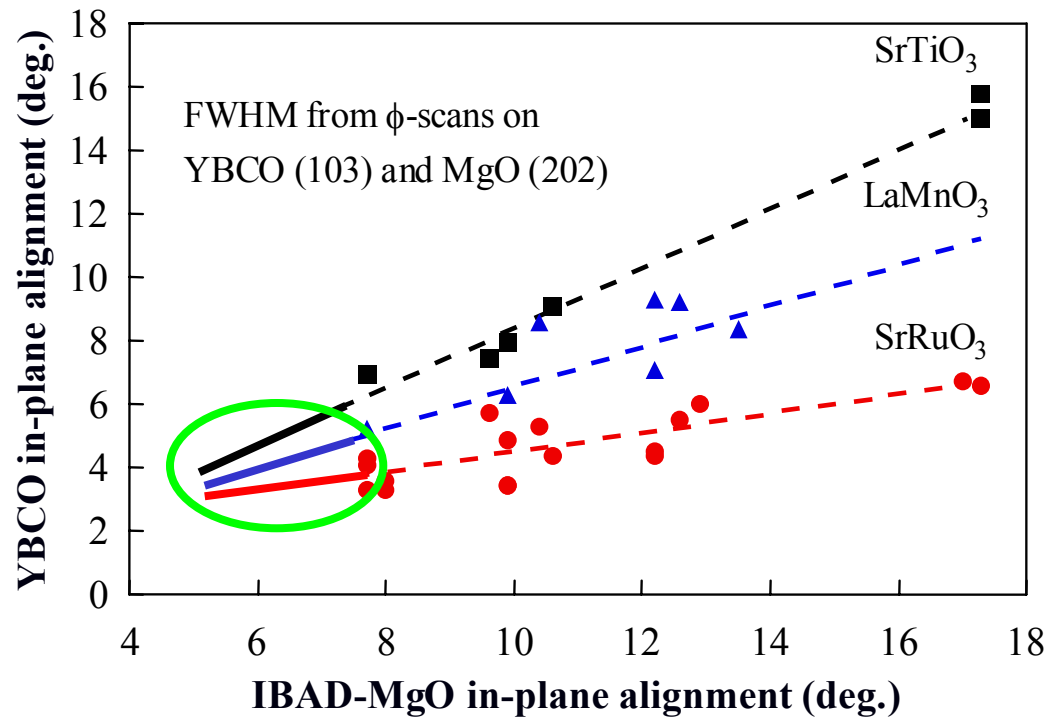


X-ray reflectivity measurement shows the surface roughness of IBAD MgO being slightly rougher than crystal MgO.

Rms { Crystal MgO ~ 0.6 nm
IBAD MgO ~ 1.0 nm



More buffer layer materials can be used due to much improved quality of IBAD MgO



SrTiO₃, LaMnO₃, or SrRuO₃ buffers provide good structural compatibility with MgO and YBCO.

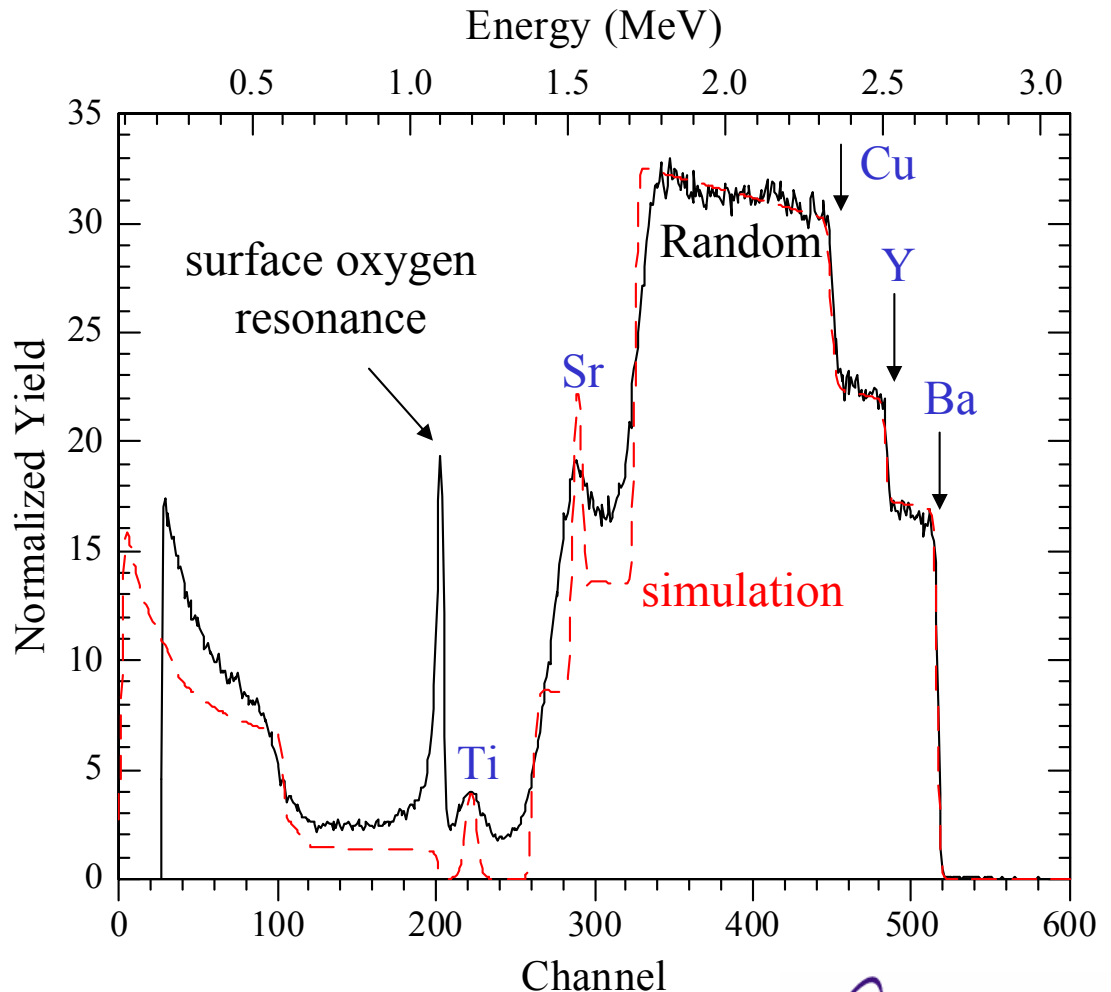
SrTiO₃ has more advantages such as

- Chemical stability
- Thermal stability
- Low cost
- High density target

Appl. Phys. Lett. **81**, 4571 (2002).

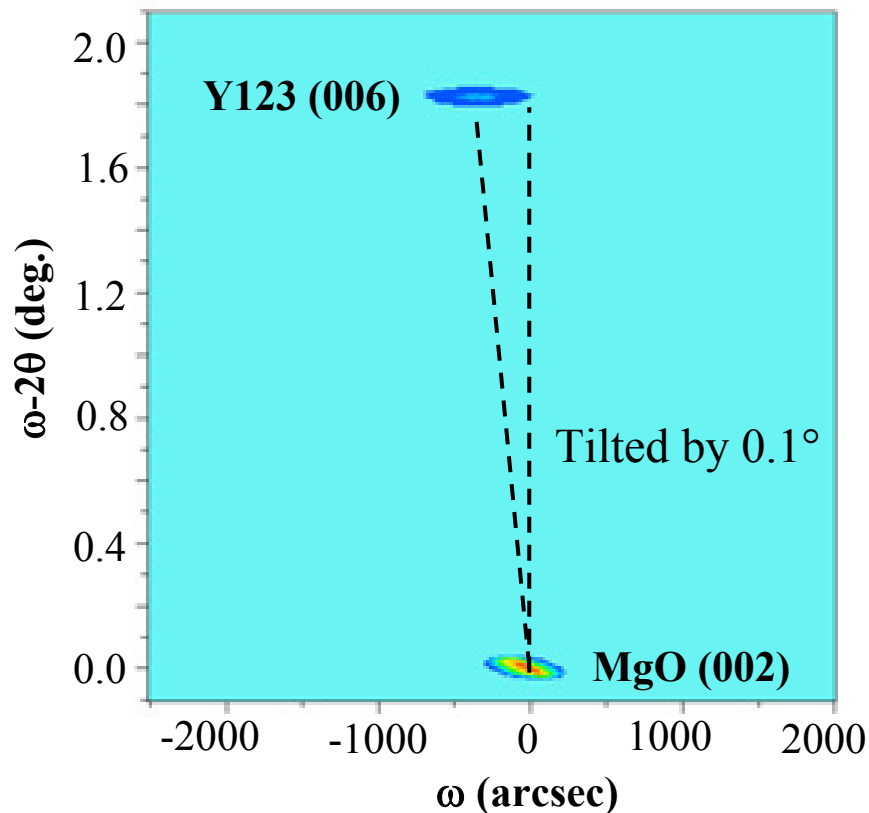
Excellent chemical composition of a thick film illustrates the feasibility of the process for coated conductors

RBS indicates good stoichiometry of the HTS thick film ($\sim 1.5 \mu\text{m}$). The chemical composition of the film is what we expect.

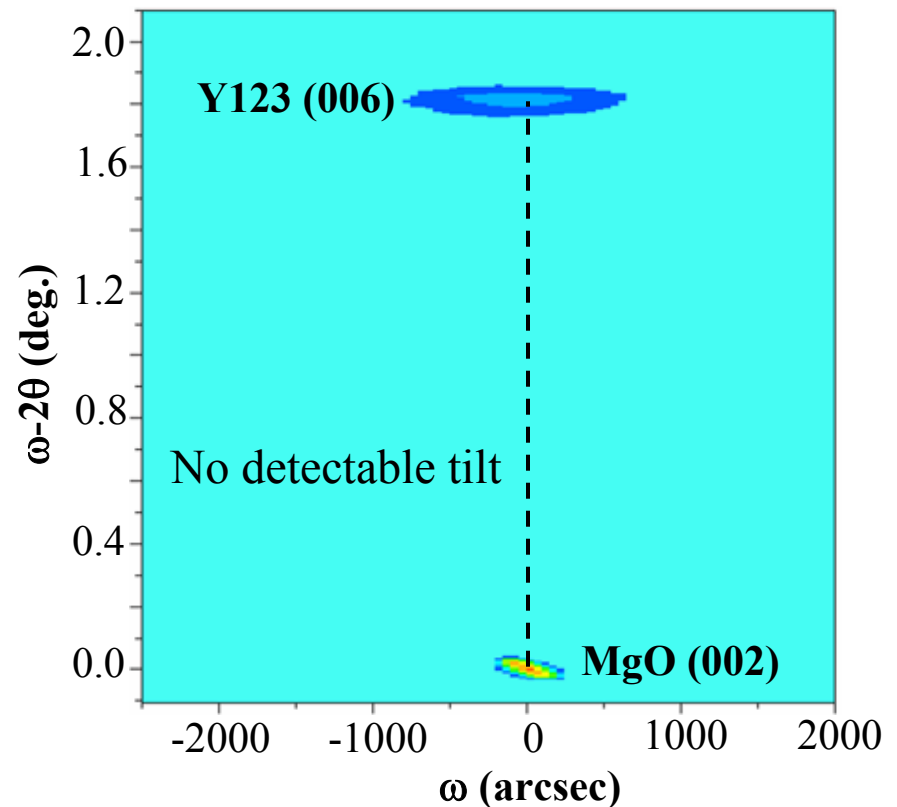


Reciprocal map illustrates reduced grain tilt with increasing film thickness for Y123 on crystal MgO

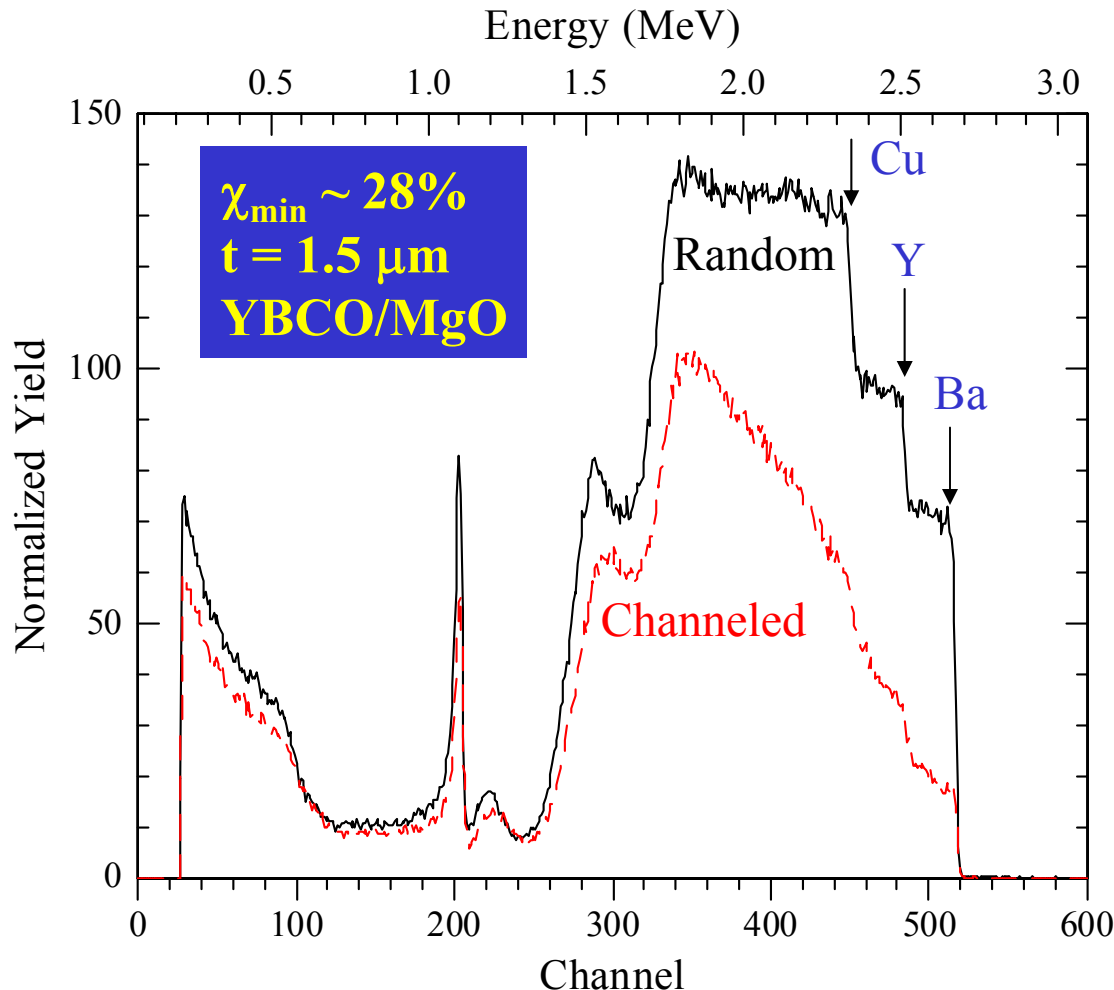
$t = 0.2 \mu\text{m}$



$t = 1.5 \mu\text{m}$



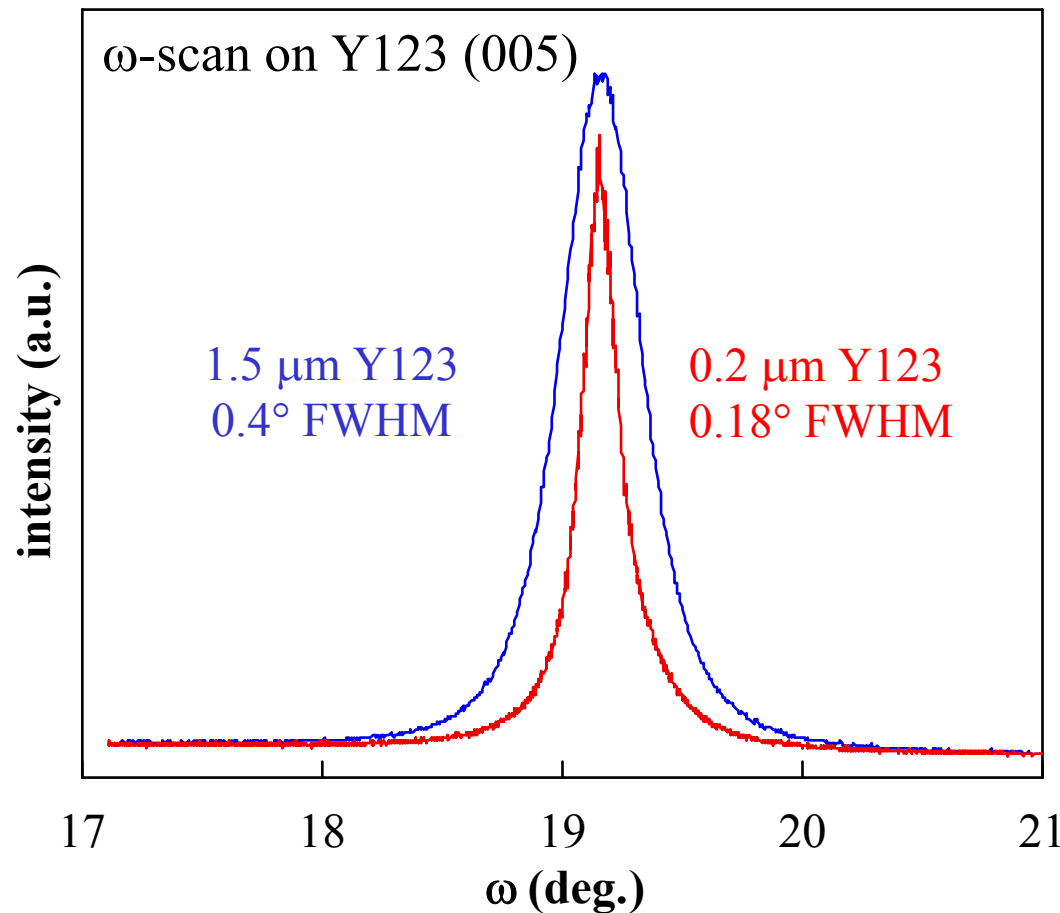
Crystalline imperfection of Y123 on crystal MgO increases with film thickness



RBS ion channeling

Low χ_{\min} is a direct indication of a good quality epitaxial layer. Point defects, impurities, dislocations, and slightly different orientations can all contribute to a large value of χ_{\min} .

Increased film thickness leads to more out-of-plane tilt, but little difference for the in-plane misorientation

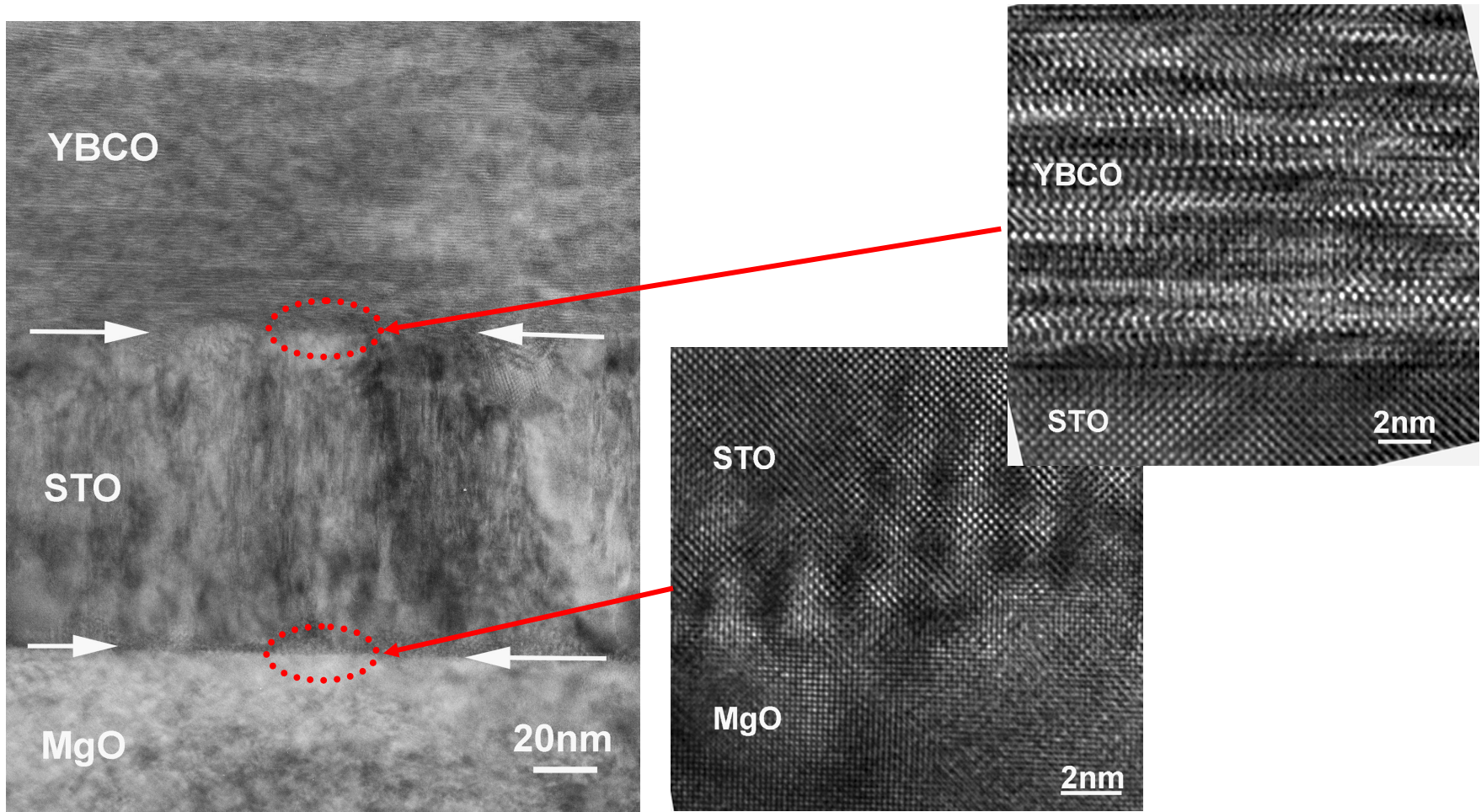


1.4° FWHM of ϕ -scan (103) for both 0.2 and 1.5 μm thick Y123 films

Ion channeling

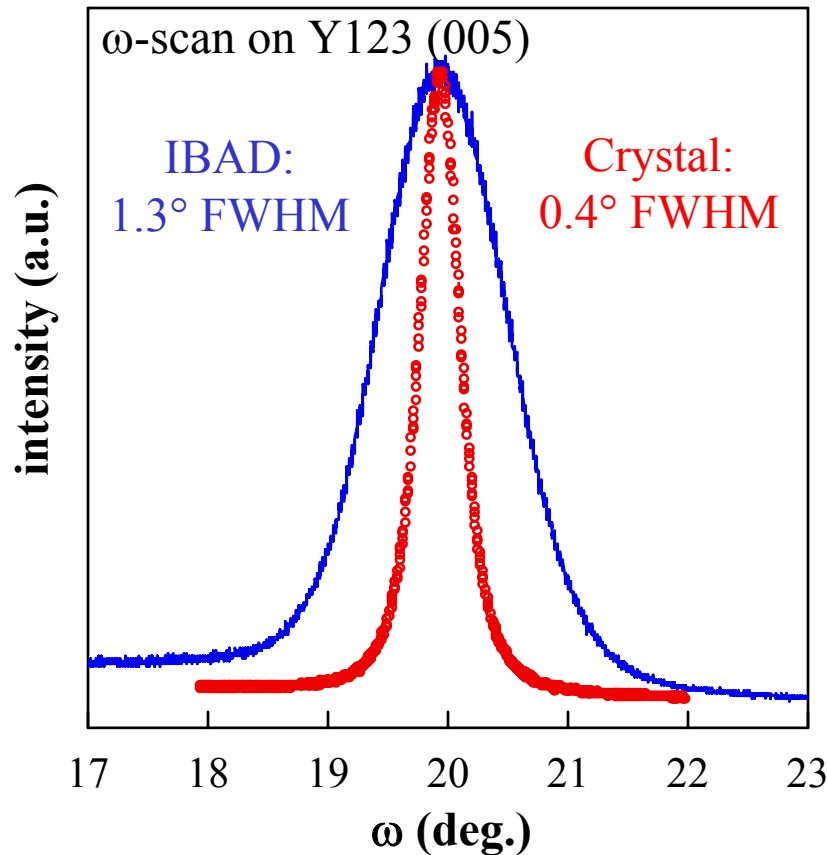
- $\chi_{\min} \sim 4\%$ for a 0.2 μm Y123 film on crystal MgO
- $\chi_{\min} \sim 28\%$ for a 1.5 μm Y123 film on crystal MgO

Thick YBCO film (1.5 μm) can be epitaxially grown on crystal MgO substrate with high crystallinity



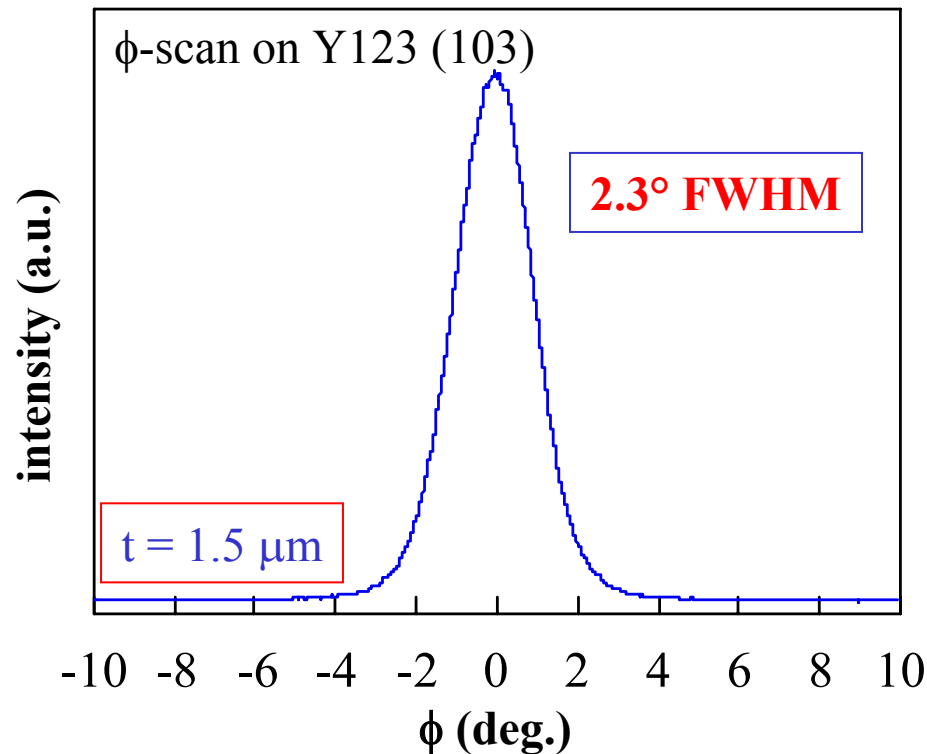
The out-of-plane tilt of thick YBCO on IBAD MgO is only 2-3 times of that on crystal substrate

$t = 1.5 \mu\text{m}$



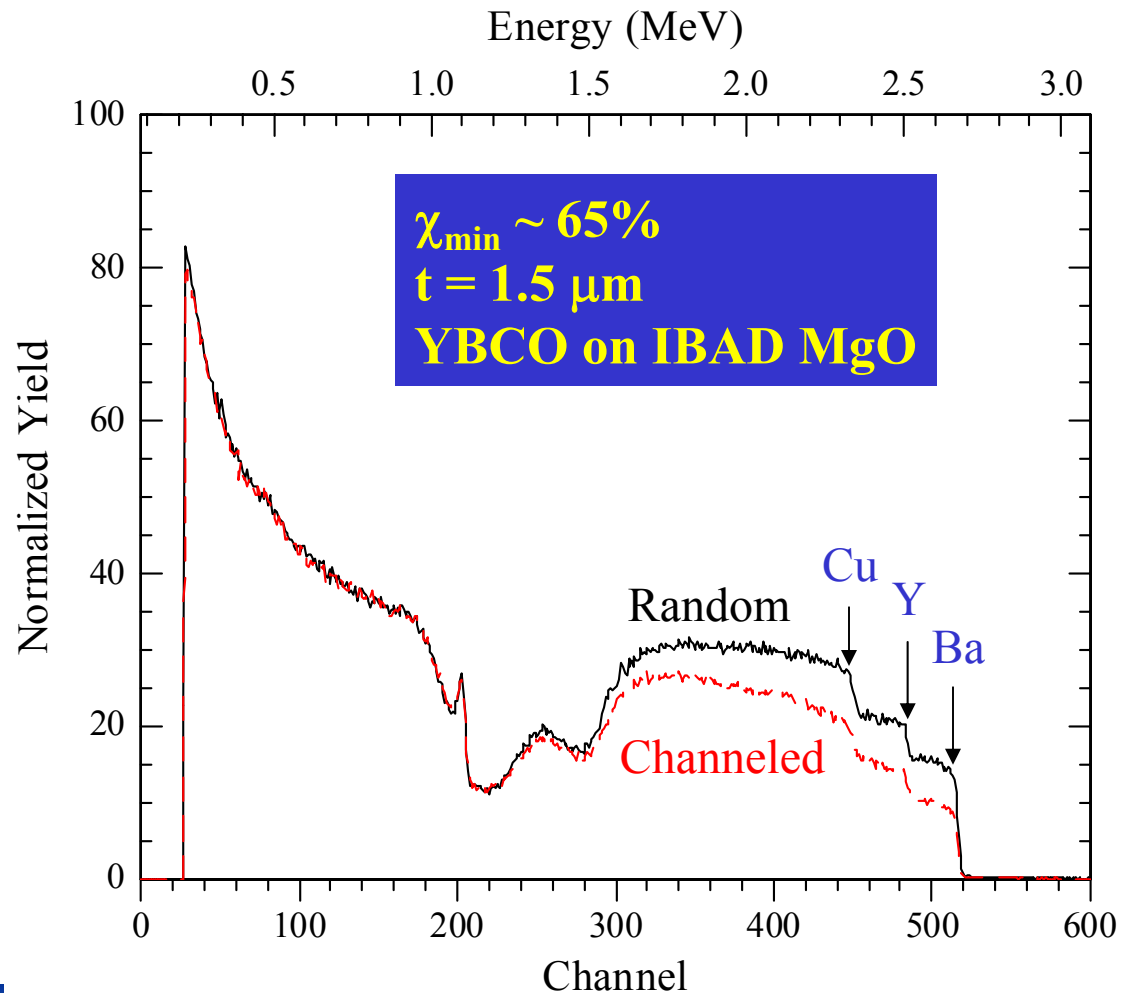
Smooth and highly crystalline IBAD MgO surface poses no limitations on surface quality for subsequent epitaxial growth of high performance HTS films.

The in-plane texture of thick YBCO film on IBAD MgO is close to that on crystal MgO substrate



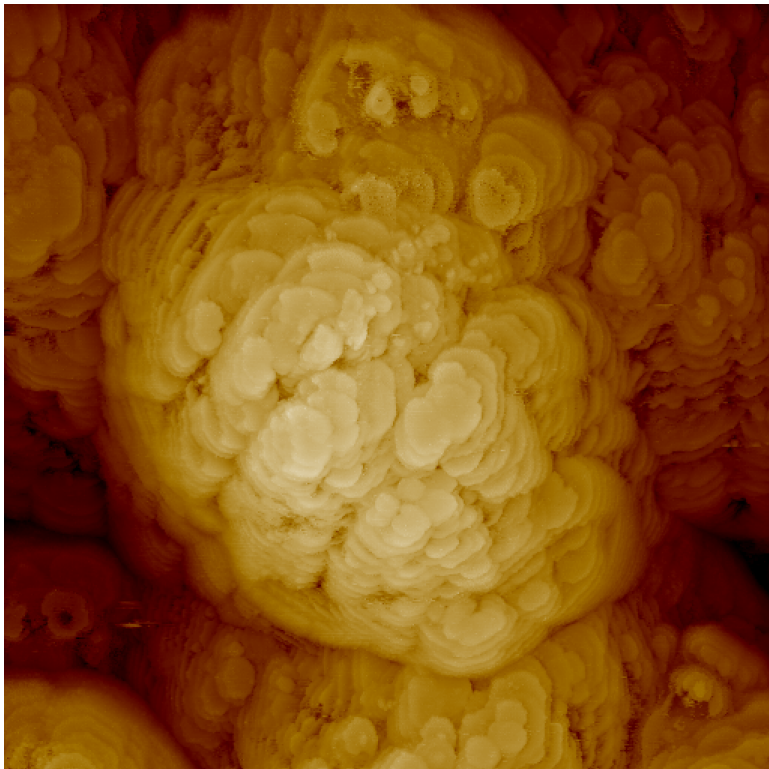
HTS film, processed under the same conditions having a thickness of 1.5 μm on crystal MgO substrate, has a typical in-plane texture of 1.4-1.7° FWHM from (103) reflection.

RBS ion channeling has been demonstrated for the first time for thick YBCO on a polycrystalline substrate



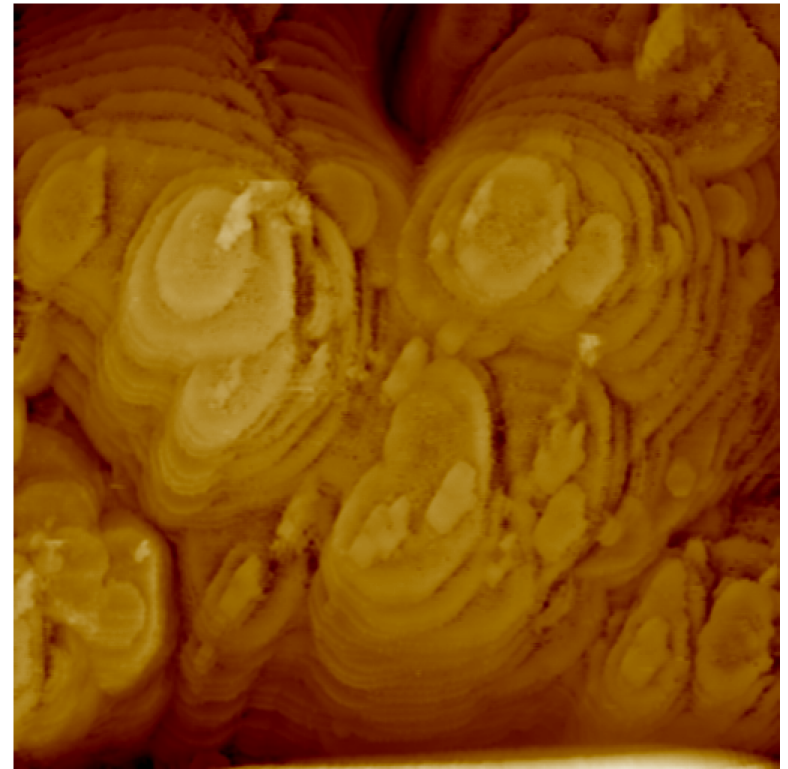
Big grains formed from small clusters comprise the surface topography of Y123 on IBAD MgO

Y123 (1.5 μm) on IBAD MgO



0

1.0 μm

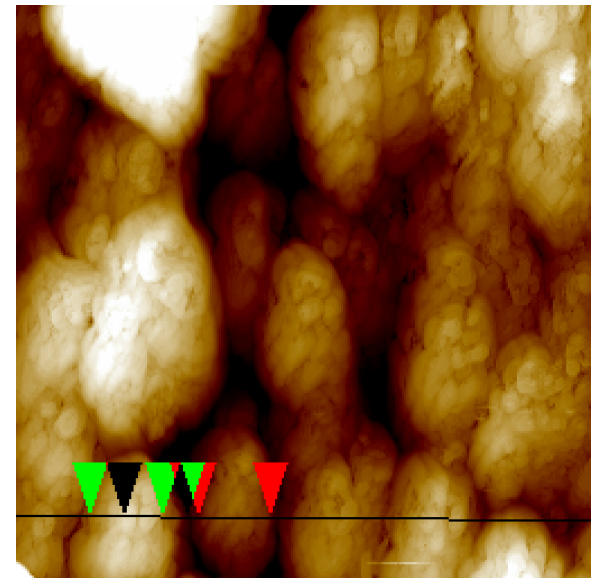
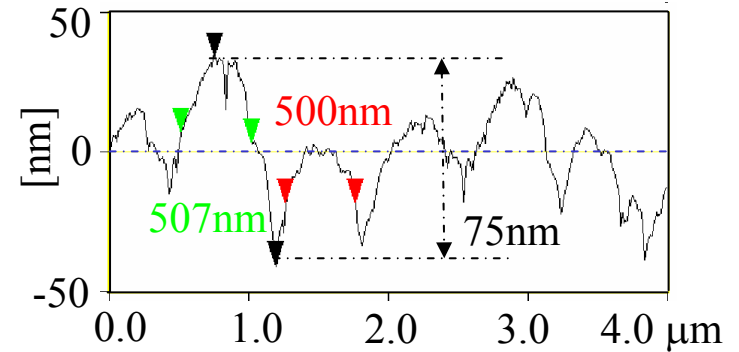
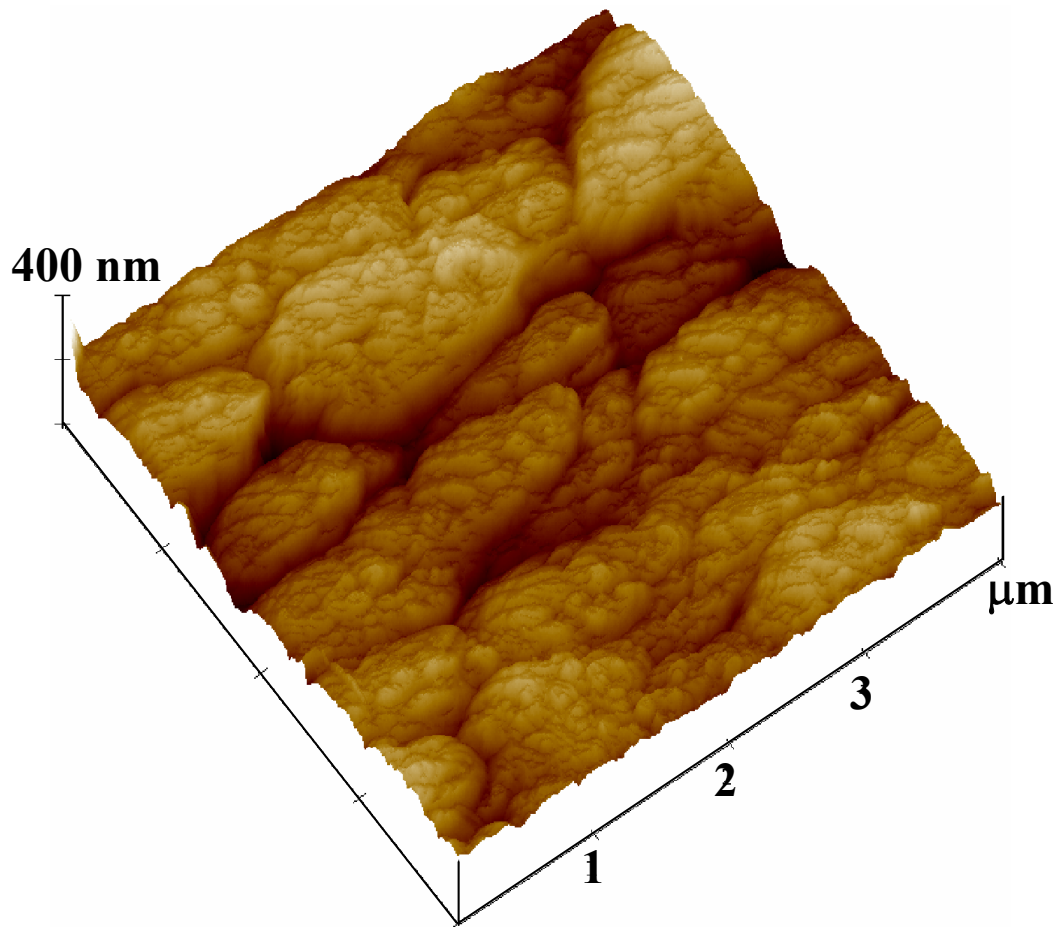


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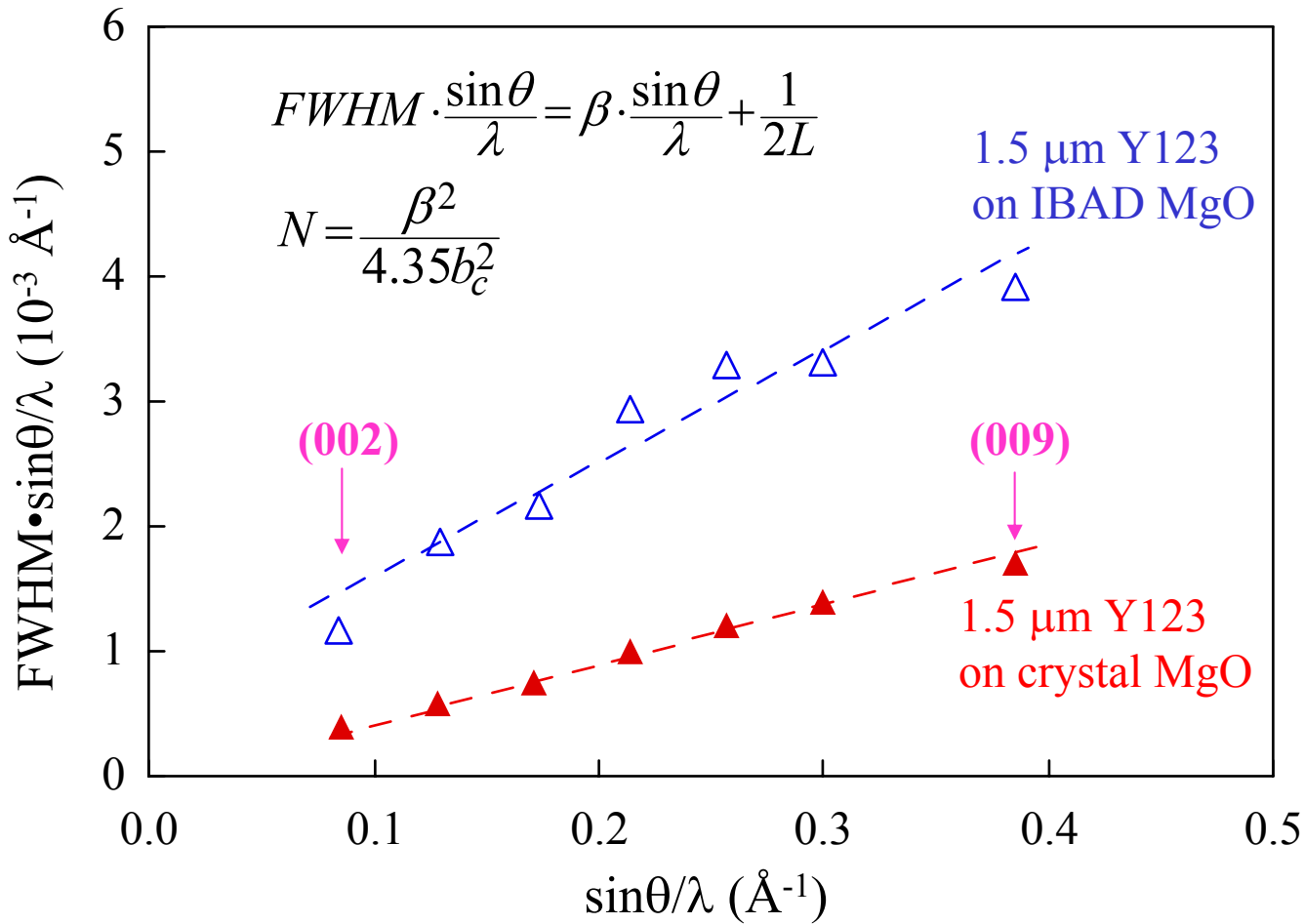
1.0 μm

Y123 (1.5 μm) on MgO crystal

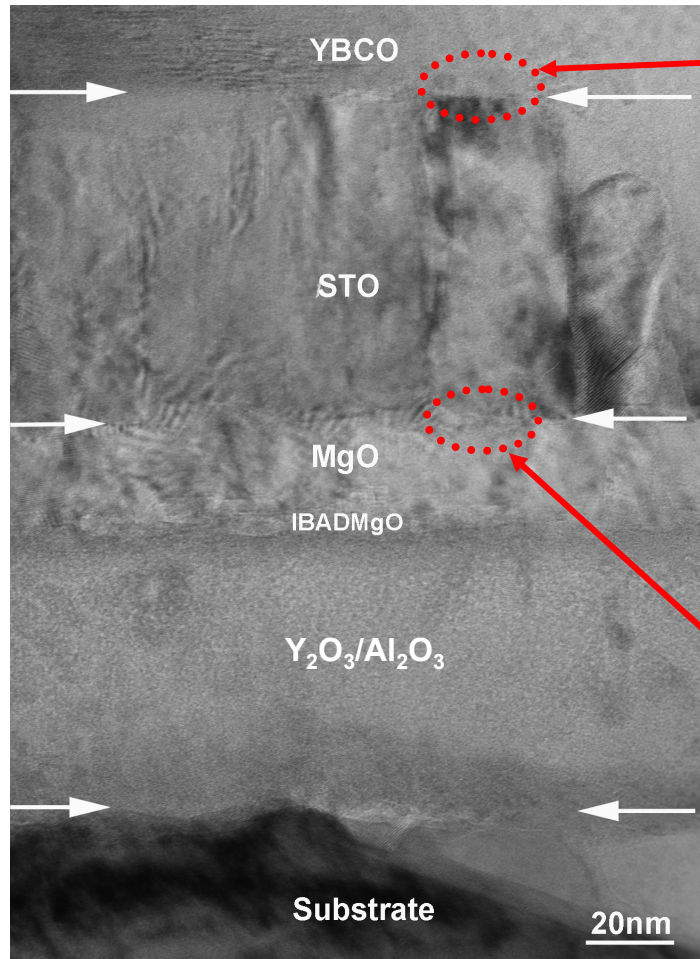
STM surface plot of a 1.5 μm thick YBCO film on IBAD MgO illustrates elongated grains



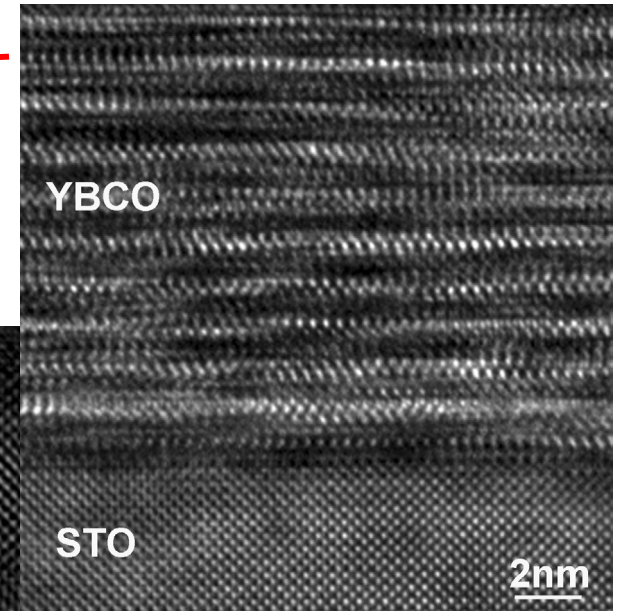
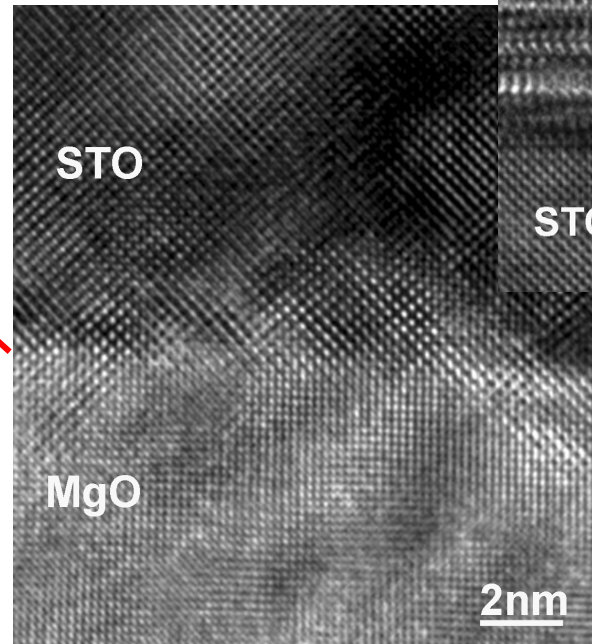
YBCO on IBAD MgO has higher ($\sim 5\times$) screw-type threading dislocation density than on crystal MgO



TEM shows good integrity for all the layers of a 1.5 μm YBCO film on IBAD MgO



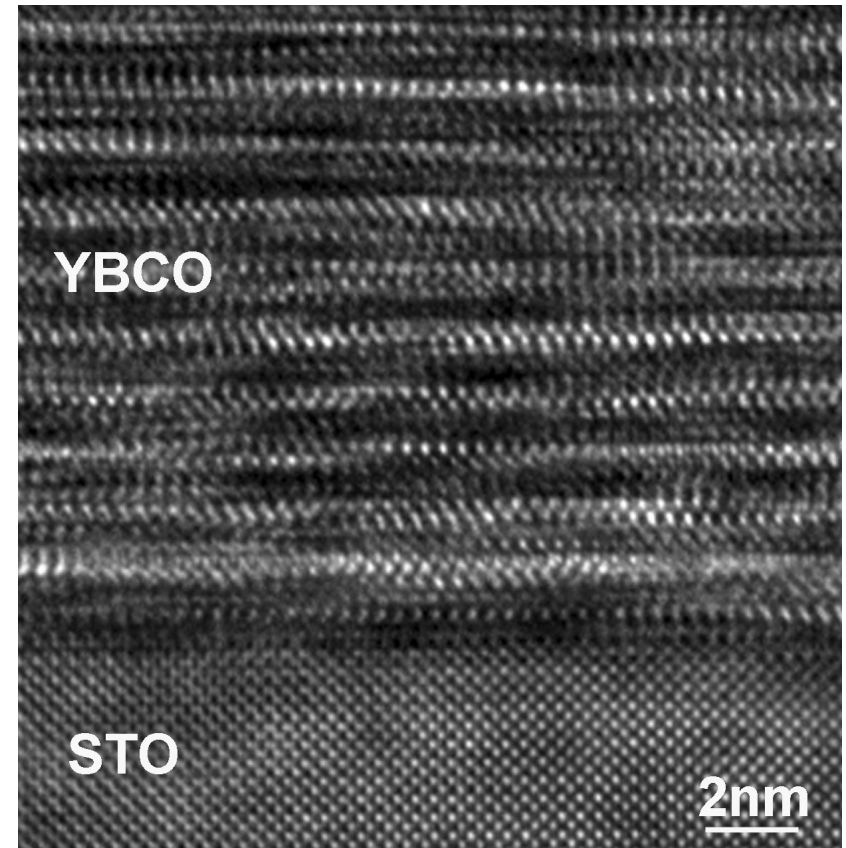
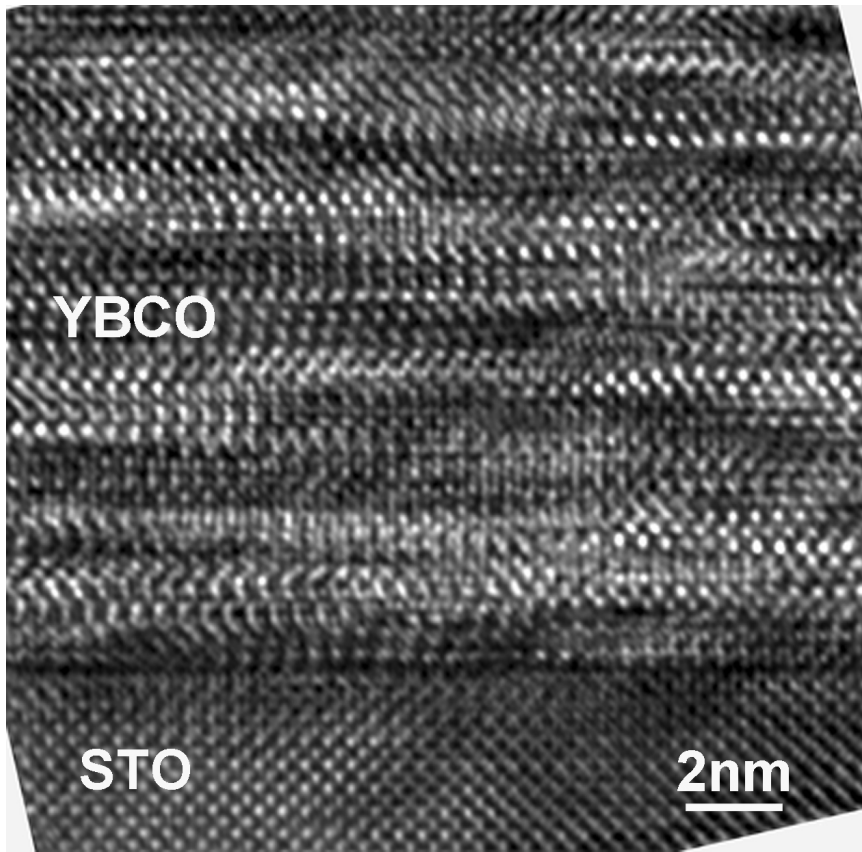
IBAD MgO provides a good template for epitaxial growth of STO buffer layer.



Sharp & clean interface between YBCO and buffer layer STO avoids the formation of 'dead layer' in between.

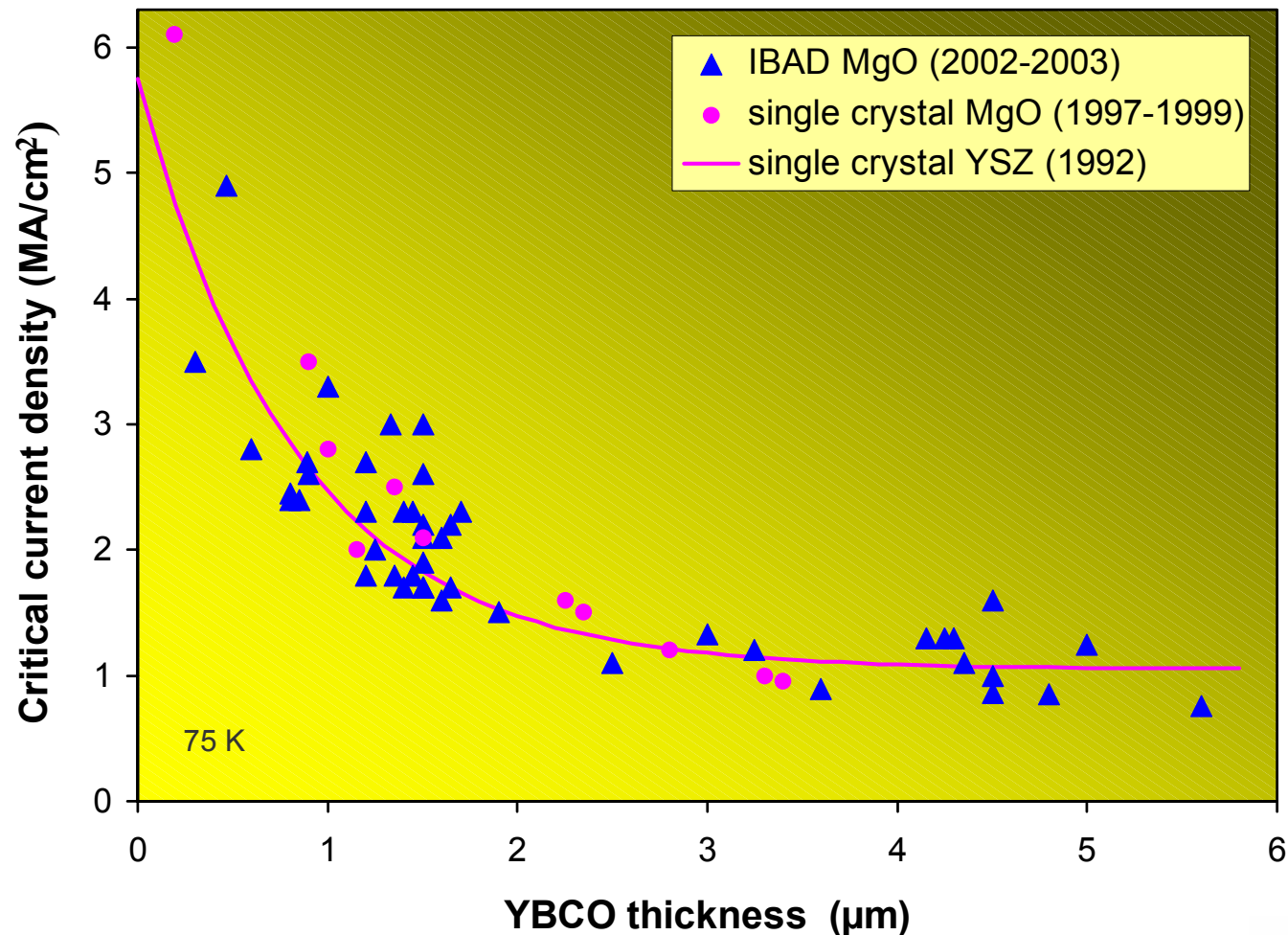
The microstructure and the interface of STO/YBCO are basically the same for the films on crystal and IBAD MgO

Crystal MgO substrate

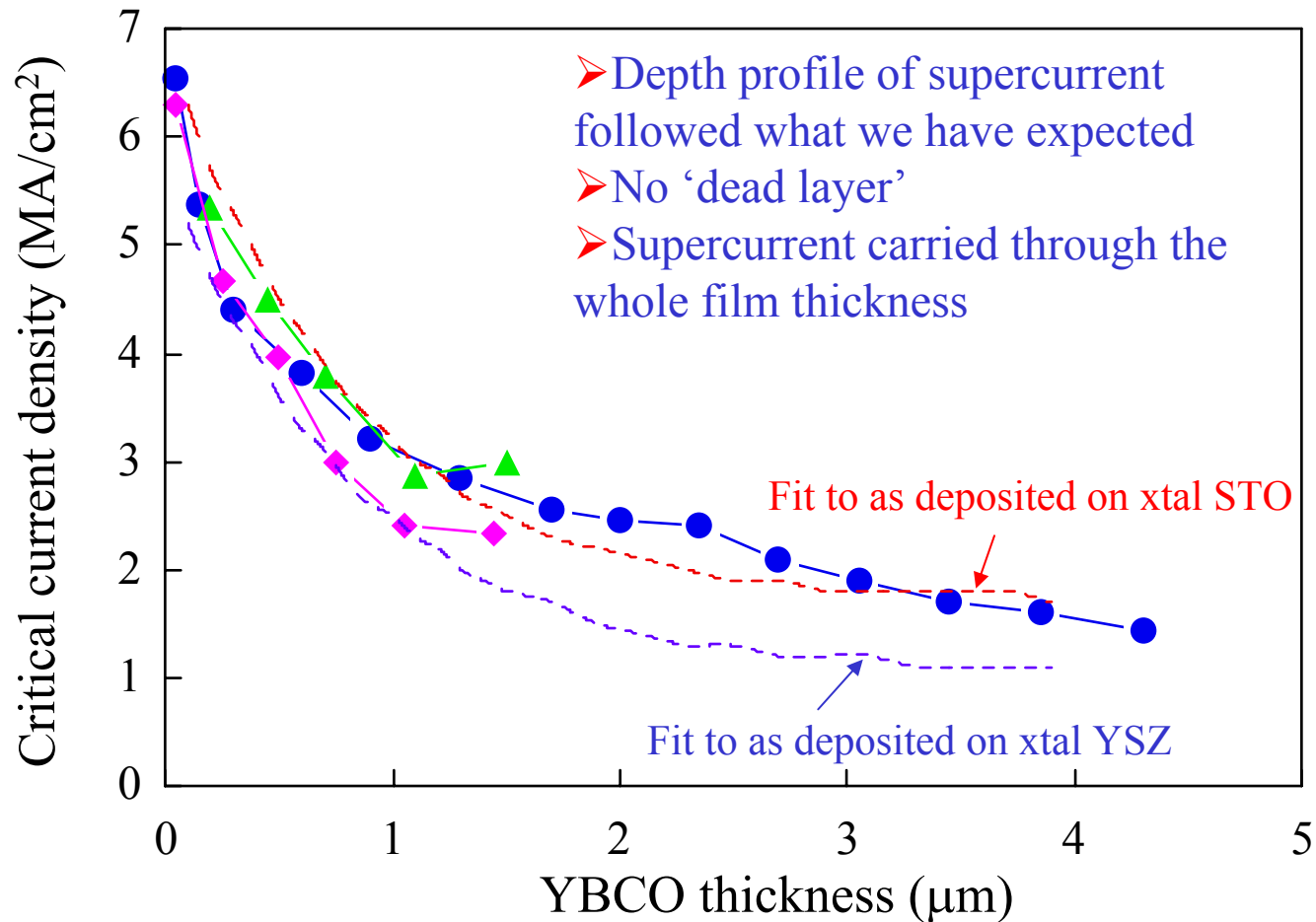


IBAD MgO substrate

HTS films on polycrystalline Ni-alloy using IBAD MgO are essentially equivalent to those on single-crystal substrates



J_c vs. thickness of ion-milled YBCO films on IBAD MgO follows the same trend as the as-deposited films on crystal MgO



Thick Y123 film on IBAD MgO performs even better in magnetic field

Leonardo Civale's talk

Summary

- Microstructural analysis illustrates that thick YBCO films on IBAD MgO are as good as the films on crystal MgO.
- Variation of microstructures with film thickness has been concluded from XRD and RBS channeling.
- Both as-deposited and ion-milled films follow the same J_c vs. thickness relationship.